bonding electrons on a surface of the thin film during the cooling solidification are terminated by hydrogen atoms in the hydrogen-containing atmosphere, wherein:

crystallization is carried out in a high energy supply apparatus that includes a generation source for generating the high energy and a supply chamber for supplying the high energy to the thin film;

E3

the thin film is set in the supply chamber;

the supply chamber has an introduction window provided in a portion of the wall of the supply chamber, for introducing the high energy into the supply chamber;

the thin film is irradiated with the high energy introduced into the supply chamber through the introduction window, the high energy passes through the introduction window along an irradiation path and travels along the irradiation path in the supply chamber; and

the high energy is supplied to the thin film with the normal direction of the thin film shifted by an angle from the direction of the irradiation path.

REMARKS

Claims 1, 2 and 4-63 are pending in this application. By this Amendment, claims 20, 25 and 46 are amended. Reconsideration and allowance are respectfully requested in view of the above amendments and the following remarks.

The attached Appendix includes a marked-up copy each amended claim (37 C.F.R. 1.121(c)(1)(ii)).

Restriction Requirement

Claims 19, 24, 29, 34, 39, 44, 45 and 50-55 have been withdrawn from consideration.

Rejection Under 35 U.S.C. §103

The Office Action rejects claims 1, 2, 4-18, 20-23, 25-28, 30-33, 35-38, 40-43 and 63 under 35 U.S.C. §103(a) over Cathey et al. ("Cathey") in view of Nakamura et al. ("Nakamura"). Applicants respectfully traverse this rejection.

Claim 1 recites a method of forming a crystalline film, comprising "crystallizing at least a surface layer of the thin film by applying energy to the surface of the thin film, at least the surface layer of the thin film being melted by the applied energy and crystallized by cooling solidification under a hydrogen-containing atmosphere;" where "unpaired bonding electrons on the surface of the thin film during the cooling solidification being terminated by hydrogen atoms in the hydrogen-containing atmosphere" (emphasis added). Claim 1 is neither taught nor suggested by the applied references.

Cathey discloses methods for forming baseplates for flat panel displays. Cathey's invention relates to macrograin polycrystalline substrates that "are relatively thick (i.e. greater than 300 microns)" (emphasis added). See col. 1, lines 58-60. One having ordinary skill in the art clearly would have understood that Cathey does not disclose methods for forming crystalline thin films, as in the claimed invention. Cathey's disclosed process for forming baseplates having thick macrograin polysilicon substrates is different from the claimed method, which utilizes thin films. Cathey does not teach or suggest any method directed to thin films.

See page 4 line 20
50 nm =
300 micron =
.3 nm =

Cathey teaches at col. 1, lines 39-45, that macro-grain polysilicon wafers are easier to make than moncrystalline wafers and also cost less. Cathey also teaches that macro-grain polysilicon is cheaper than using glass substrates. Cathey teaches methods of substantially minimizing or eliminating grain boundaries 1 in a substrate 11. In the embodiment shown in Fig. 3D, Cathey recrystallizes or reforms amorphous or polysilicon 8 with a laser to form single crystal silicon. See col. 5, lines 63-68 of Cathey. However, Cathey also does not teach or suggest using any particular atmosphere during laser irradiation of the thick substrate. Thus, Cathey further does not teach or suggest using a hydrogen-containing atmosphere as in claim 1.

second embodiment

3rd embodiment At col. 6, lines 49-58, Cathey discloses another separate embodiment that uses macro-grain polycrystalline substrate 11 "as it is" (emphasis added). That is, the substrate is not subjected to a recrystallization step, but is used in the polycrystalline form. Cathey teaches that for such polycrystalline substrates, the grain boundaries can be hydrogenated. However, Cathey does not teach or suggest "crystallizing at least a surface layer of the thin film by applying energy to the surface of the thin film, at least the surface layer of the thin film is melted by the applied energy and crystallized by cooling solidification under a hydrogen-containing atmosphere," as recited in claim 1. Rather, Cathey only teaches that the grain NO boundaries can be hydrogenated in "as is" material, but without crystallizing at least a surface 1st embodiment layer of the polycrystalline substrate. Cathey also does not teach or suggest that melting at least a surface layer of the polycrystalline substrate would be desirable for any reason in this embodiment. In fact, Cathey teaches directly against such melting or crystallizing any portion of the polycrystalline substrate, because the substrate is used "as it is," i.e., not recrystallized. Cathey thus also fails to teach or suggest such recrystallization in combination with cooling solidification under a hydrogen-containing atmosphere.

Nakamura provides no teaching, suggestion or motivation to modify Cathey's process to achieve the claimed invention. Nakamura crystallizes amorphous silicon into polycrystalline silicon using a laser. See col. 4, line 33 to col. 5, line 35 of Nakamura. inherent Nakamura does not teach or suggest melting a surface layer of the polycrystalline silicon during the crystallization process. Nakamura thus also does not teach or suggest that "unpaired bonding electrons on the surface of the thin film during the cooling solidification are terminated by hydrogen atoms in the hydrogen-containing atmosphere" (emphasis added). col 5 line 51-53

Nakamura does not provide any motivation to modify Cathey's embodiment shown in Fig. 3D to use a hydrogen-containing atmosphere. As stated above, for this particular embodiment, Cathey does not teach or suggest that any particular atmosphere should be used

during the laser treatment of the substrate. Cathey thus does not teach or suggest that a hydrogen-containing atmosphere should be used. Moreover, in this embodiment of Cathey, the amorphous or polysilicon layer 8 is recrystallized or reformed. Cathey does not teach or suggest that the recrystallized or reformed material should be hydrogenated in order to improve electron mobility within the substrate.

As stated above, in the embodiment described at col. 6, lines 49-58 of Cathey, the grain boundaries are hydrogenated. However, this embodiment performs hydrogenation with respect to macro-grain polycrystalline substrates, which are used "as is," and <u>not</u> to substrates that are subjected to recrystallization. Cathey does not teach or suggest that hydrogenation is necessary, or even would be desirable, for substrates that have been subjected to recrystallization or reforming, as in the embodiment shown in Fig. 3D. In fact, in view of its disclosure at col. 6, lines 49-58, Cathey teaches against using hydrogenation of grain boundaries in the embodiment of Fig. 3D.

No Cathey col 5 lines 50-53

Thus, Cathey teaches against using hydrogenation in embodiments that perform laser recrystallizing or reforming of amorphous or polysilicon materials, such as shown in Fig. 3D. Therefore, the combined teachings of Cathey and Nakamura would not have taught or suggested modifying Cathey's process to perform the step of "crystallizing at least a surface layer of the thin film by applying energy to the surface of the thin film, at least the surface layer of the thin film is melted by the applied energy and crystallized by cooling solidification under a hydrogen-containing atmosphere," such that "unpaired bonding electrons on the surface of the thin film during the cooling solidification are terminated by hydrogen atoms in the hydrogen-containing atmosphere," as recited in claim 1.

Thus, claim 1 would not have been rendered obvious by Cathey and Nakamura. Claims 2 and 5-11 depend from claim 1 and accordingly are also allowable for at least the same reasons stated for claim 1.

Claim 12 is directed to a method of forming a crystalline film, which comprises "crystallizing at least a surface layer of the semiconductor thin film by applying energy to the surface of the semiconductor thin film, at least the surface layer of the semiconductor thin film is melted by the applied energy and crystallized by cooling solidification under an atmosphere containing a gas containing the component element of the semiconductor thin film and hydrogen"; and "unpaired bonding electrons on the surface of the semiconductor thin film during the cooling solidification are terminated by hydrogen atoms in the atmosphere " (emphasis added). Claim 12 also would not have been rendered obvious by Cathey and Nakamura for the reasons stated above. Furthermore, Nakamura only teaches the use of hydrogen plasma atmospheres. Nowhere does Nakamura teach or suggest using a gas containing a "component element of the semiconductor thin film and hydrogen" (emphasis added), as claimed. Claims 13-18 depend from claim 12 and accordingly are also allowable.

inherent Si film.

Instant claim 20 also recites the step of "crystallizing." In addition, claim 20 recites "positioning the introduction window relative to the thin film at a location resistant to adherence of components of the thin film when the high energy is supplied to the thin film" (emphasis added). The recited method thus includes positioning the introduction window relative to the thin film, and particularly "at a location resistant to adherence of components of the thin film when the high energy is supplied to the thin film." This language is not merely "functional language" as asserted in the Office Action. Rather, this language is a positive step of the claimed method. Furthermore, even if the recited language were functional language, which it is not, the recited feature must still be taught or suggested by the applied references. However, neither Cathey nor Nakamura teaches or suggests this feature of the recited method. The Office Action states no reason why this feature would be inherent in Cathey or Nakumura; neither of these references discloses any positioning of an introduction window relative to a thin film. Cathey does not even in the first place disclose

why
Nowhere?

any such introduction window. Nakamura is completely silent regarding any specific spacing of the window 52 and the amorphous silicon 53 shown in Fig. 6, or even that this spacing is of any concern or important for any reason. The Office Action states no reason why this claimed result would inherently occur in Nakamura in the absence of any teaching or suggestion regarding this result.

w/o inclusion

In contrast, the present specification explains that the introduction window needs to be sufficiently separated from the object material to be crystallized, as compared to the scattering range of the object material, so that the components of the object material hardly adhere to the introduction window. Nakamura does not disclose this feature, either expressly or inherently. In order to establish that a certain result is inherent, it must be established that the inherency is a necessary result and not merely one possible result; the mere fact that a certain thing may result from a given set of circumstances is not enough. In re Oelrich, 212 USPQ 323, 326 (CCPA 1981). Thus, even if one possible location of the window 52 and the amorphous silicon 53 shown in Fig. 6 of Nakamura may be the claimed positioning of the introduction window, which Nakamura does not teach or suggest, such mere possibility would still not establish the asserted inherency, because other positions of the introduction window relative to the amorphous that are different from the claimed positioning are also possible.

so what

Moreover, Nakamura does not teach or suggest that any advantage may be gained by any certain positioning of the window 52 relative to the amorphous silicon 53. Thus, Nakamura does not teach or suggest that by using the claimed positioning, components of the amorphous material would hardly adhere to the window 52, as in the claimed invention.

very unclear

Thus, Cathey and Nakamura would not have rendered obvious the method of claim 20. Claims 21-23 depend from claim 20 and, accordingly, are also allowable.

Independent claim 25 is directed to a method of forming a crystalline film, which also comprises the above-identified "crystallizing" step. Claim 25 also recites "positioning the

introduction window relative to the thin film so that a distance between the introduction window and the thin film is larger than a shortest distance between the wall and the thin film when the high energy is supplied to the thin film." This claimed feature also contributes to reducing or preventing the adherence of components of the thin film on the introduction window when the high energy is applied to the thin film. For the reasons stated above, neither Cathey nor Nakamura teaches or suggests the method of claim 25.

Thus, Cathey and Nakamura would not have rendered obvious claim 25. Claims 26-28 depend from claim 25 and, accordingly, are also allowable.

Independent claim 30 also recites the above-described "crystallizing" step. Claim 30 further recites "the high energy is supplied to the thin film under a pressure in a vicinity of the introduction window that is higher than a pressure in the vicinity of the thin film in the supply chamber". Neither Cathey nor Nakamura teaches or suggests the claimed method.

As stated, Cathey does not even teach a window. Nakamura teaches no specific relationships between the pressures in the vicinity of the window 52 and in the vicinity of the silicon 53. Thus, Nakamura does not specifically teach that the pressure in the vicinity of the window 52 is higher than in the vicinity of the silicon 53.

Therefore, Cathey and Nakamura would not have rendered obvious claim 30. Claims 31-33 depend from claim 30 and accordingly are also allowable.

Independent claim 35 also would not have been rendered obvious by Cathey or Nakamura for at least the same reasons as claim 30. Claims 36-38 depend from claim 35 and accordingly are also allowable.

Independent claim 40 is directed to a method of forming a crystalline film. Claim 40 recites the above-described step of "crystallizing." Neither Cathey nor Nakamura teaches or suggests this step. Claim 40 also recites "gas flow from the introduction window to the thin

film in approximately the same direction as the irradiation path." Neither Cathey nor Nakamura teaches or suggests the method of claim 40.

Cathey does not teach an introduction window. Cathey also provides no description regarding the path of the laser emission shown in Fig. 3D.

The Nakamura device shown in Fig. 6 introduces gas into the chamber 51 through the inlet 60 in a direction that is perpendicular to the path of the laser beam. Nakamura does not teach or suggest a "gas flow from the introduction window to the thin film in approximately the same direction as the irradiation path" (emphasis added), as claimed. Thus, the applied references do not support the rejection of claim 40.

see fig. 6 gas inlet 60 + outlet 61 ∴ flow same as path ⊥ to laser beam

For the foregoing reasons, claim 40 would not have been rendered obvious by the applied references. Claims 41-43 depend from claim 40 and, accordingly, are also allowable.

Therefore, Applicants respectfully request that the rejection of claims 1, 2, 4-18, 20-23, 25-28, 30-33, 35-38, 40-43 and 63 under 35 U.S.C. §103(a) be withdrawn.

Claims 46-49 and 56-63

The Office Action does not state any grounds of rejection for claims 46-49 and 56-63. However, it appears from the Office Action that these claims have been rejected over Cathey in view of Nakamura and further in view of JP 58-90722 ("JP '722"), in light of the express mention of JP 58-90722 beginning at page 7, line 19 of the Office Action. Applicants following remarks assume that JP 58-90722 is being applied in combination with Cathey and Nakamura in the rejection of claims 46-49 and 56-63.

Claim 46 is directed to a method of forming a crystalline film. Claim 46 recites the step of "crystallizing" as discussed above. JP '722, like Nakamura, provides no teaching, suggestion or motivation to modify Cathey to include this feature.

Claim 46 also recites that "the thin film is irradiated with the high energy introduced into the supply chamber through the introduction window, the high energy passes through the introduction window along an irradiation path and travels along the irradiation path in the

supply chamber," and "the high energy is supplied to the thin film with the normal direction of the thin film shifted by an angle from the direction of the irradiation path" (emphasis added). The applied references fail to teach or suggest the method of claim 46. Regarding JP '722, even if some reflection of a light beam by a thin film occurs, JP '722 still does not teach or suggest that "the high energy passes through the introduction window along an irradiation path and travels along the irradiation path in the supply chamber," as claimed.

Furthermore, in Fig. 2, JP '722 shows energy 10 being directed onto polycrystalline silicon 3, forming single crystal regions 3' with angled walls. The Office Action states no motivation for modifying Cathey to include this feature of JP '722. Cathey does not form any such openings in polycrystalline silicon. The Office Action states no reason to form such openings in Cathey's thick substrates. Cathey uses a laser for recrystallizing or reforming amorphous or polysilicon material, and not for forming openings in these materials.

Thus, claim 46 would not have been rendered obvious. Claims 47-49 depend from claim 46 and, accordingly, are also allowable.

Regarding claim 56, JP '722 also provides no teaching, suggestion or motivation to modify Cathey to include the recited "crystallizing."

In addition, neither Cathey, Nakamura nor JP '722 teaches or suggests the recited feature that "when a first position of the thin film is irradiated with the high energy introduced into the supply chamber, part of the high energy enters the thin film" and "another part of the high energy is reflected by the thin film to form reflected energy that irradiates a second position of the thin film through a course change of the reflected energy." None of these references teach or suggest a thin film that reflects energy such that a reflected part of the high energy irradiates a second portion of the thin film. Neither Cathey nor Nakamura shows any reflection by a thin film. JP '722 appears to show reflection of energy 10. However, this disclosure does not suggest that the reflected energy is reflected to irradiate a second portion of the layer 3.

Thus, claim 56 is believed to be allowable. Claims 57-61 are also allowable for at least the same reasons as claim 56.

Claim 62 depends from claim 1 and thus also would not have been rendered obvious by the applied references.

Therefore, Applicants respectfully request that the rejection of claims 46-49 and 56-63 be withdrawn.

For the foregoing reasons, withdrawal of the rejections and allowance of the pending claims are respectfully requested.

Should the Examiner believe anything further is desirable to place the application in even better condition for allowance, the Examiner is invited to contact Applicants' undersigned attorney at the telephone number listed below.

Respectfully submitted,

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JAO:EAB/ldg

Attachment:
Appendix

Date: November 16, 2001

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DEPOSIT ACCOUNT USE AUTHORIZATION
Please grant any extension necessary for entry;
Charge any fee due to our Deposit Account No. 15-0461

APPENDIX

Changes to Claims:

The following are marked-up versions of the amended claims:

20. (Four Times Amended) A method of forming a crystalline film, comprising:

forming a thin film on a substrate;~~and~~

setting the thin film in a supply chamber of a high energy supply apparatus including a generation source for generating the high energy and the supply chamber for supplying the high energy to the thin film, the supply chamber including an introduction window that introduces the high energy into the supply chamber;

crystallizing at least a surface layer of the thin film by supplying high energy to the thin film under a hydrogen-containing atmosphere, at least the surface layer of the thin film ~~is~~ being melted by the high energy and crystallized by cooling solidification, and unpaired bonding electrons on a surface of the thin film during the cooling solidification ~~are~~ being terminated by hydrogen atoms in the hydrogen-containing atmosphere~~, wherein:~~;

~~crystallizing is carried out in a high energy supply apparatus which includes a generation source for generating the high energy and a supply chamber for supplying the high energy to the thin film;~~

~~the thin film is set in the supply chamber;~~

~~the supply chamber includes an introduction window that introduces the high energy into the supply chamber;~~ and

~~the high energy is supplied to the thin film with~~ positioning the introduction window ~~disposed~~ relative to the thin film at a location resistant to adherence of components of the thin film when the high energy is supplied to the thin film.

25. (Four Times Amended) A method of forming a crystalline film, comprising:

forming a thin film on a substrate;~~and~~

setting the thin film in a supply chamber of a high energy supply apparatus which including a generation source for generating the high energy and the supply chamber for supplying the high energy to the thin film, the supply chamber including a wall and an introduction window provided in a portion of the wall, the introduction window introducing the high energy into the chamber; ~~and~~

crystallizing at least a surface layer of the thin film by supplying high energy to the thin film under a hydrogen-containing atmosphere, at least the surface layer of the thin film ~~is~~ being melted by the high energy and crystallized by cooling solidification, and unpaired bonding electrons on a surface of the thin film during the cooling solidification ~~are~~ being terminated by hydrogen atoms in the hydrogen-containing atmosphere~~, wherein:~~;

~~crystallizing is carried out in a high energy supply apparatus which includes a generation source for generating the high energy and a supply chamber for supplying the high energy to the thin film, wherein:~~

~~the thin film is set in the supply chamber;~~

~~the supply chamber includes a wall and an introduction window provided in a portion of the wall, the introduction window introduces the high energy into the chamber;~~ and

~~the high energy is supplied to~~ positioning the introduction window relative to the thin film ~~with~~ so that a distance between the introduction window and the thin film being larger than a shortest distance between the wall and the thin film when the high energy is supplied to the thin film.

46. (Four Times Amended) A method of forming a crystalline film, comprising:

forming a thin film on a substrate; and

crystallizing at least a surface layer of the thin film by supplying high energy to the thin film under a hydrogen-containing atmosphere, at least the surface layer of the thin

film is melted by the high energy and crystallized by cooling solidification, and unpaired bonding electrons on a surface of the thin film during the cooling solidification are terminated by hydrogen atoms in the hydrogen-containing atmosphere, wherein:

crystallization is carried out in a high energy supply apparatus that includes a generation source for generating the high energy and a supply chamber for supplying the high energy to the thin film;

the thin film is set in the supply chamber;

the supply chamber has an introduction window provided in a portion of the wall of the supply chamber, for introducing the high energy into the supply chamber;

the thin film is irradiated with the high energy introduced into the supply chamber through the introduction window, the high energy passes through the introduction window along an irradiation path and travels along ~~a~~ the irradiation path ~~assumed~~ in the supply chamber; and

the high energy is supplied to the thin film with the normal direction of the thin film shifted by an angle from the direction of the irradiation path.